BooNE MC status,   March 18 2016

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With help from Zarko & Alberto

Outline: Moving to v4.10

- Limited amount of new code needed to be written
  - And a bit more, which will be the subject of the 1rst part of this meeting.
  - Status: Code written, compiles, runs.
  - This port is complete, pending new code to support new validation, new output Ntuples..
- Intermediate results:
  - Pion spectra after Horn.
- Discussion on more diagnostics??

More information about scattering..

- A recent addition to both v4p9 and v4p10: The Dk2nu neutrino ancestry now includes hadronic scattering information. To be precise, if a step process name does not corresponds to a step whose lengths has been selected based on anything else but e.m. process, or geometry, a temporary d/s if filled, and should a neutrino be created and submitted to Dk2nu output, the ancestry list will be update with the additional information about such scattering occurrences
- Adds a bit of output, but worth while.. Status: coded, checked on a few events in v4p9. Not yet exploited in any given analysis.

Implementing the HARP/MiniBooNE model in G4, v4.10..

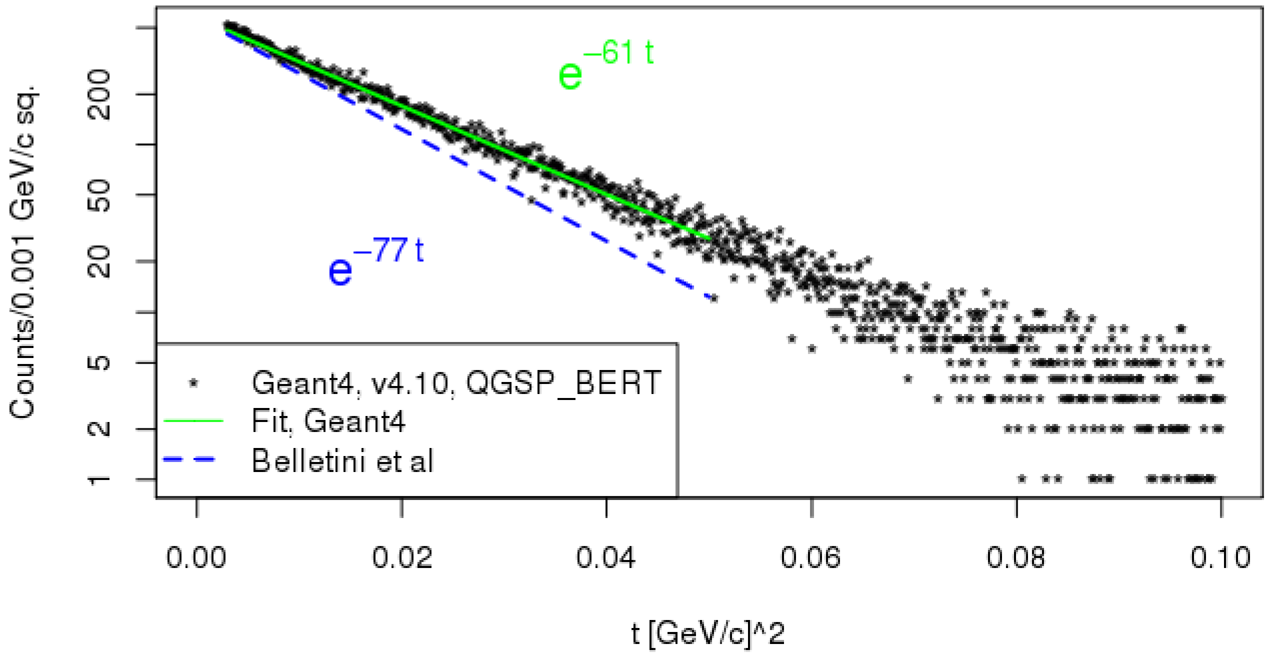
- Avoid the creation of a new private Physics List.
  - No longer encouraged by G4 team, unless done in close cooperation with G4 experts. (No supported API for it..)
  - Since the HARP/MiniBoone model is inclusive, and only valid for proton on Beryllium, do we really need a Physics list, capable of handling many process.
  - Even to the point, I need think we need a G4 process defined..
- The proposal: implemented in G4PrimaryGeneratorAction level:
  - A G4 Primary vertex can hold more than primary particle, with or without kinematical constraints.
  - Implementing the correct radial and Z position ought to be straightforward..

Simulation of 8 GeV protons to the interaction point..(-> BooNE model)

- In between the upstream edge of the target and the (likely, but not assured) interaction point, things can happen..
- At first, the plan was to simulate only multiple scattering (Gaussian) and energy loss.
- Unfortunately, the tail of the radial position distribution, v4p10 vs v4p9 (and v4p8) did not match very well..
- I forgot p->Be elastic (Quasi-elastic ?) scattering!...
  - At 8 GeV: as shown later, (i) the average scattering angle is ~10 mRad (ii) The X-section is about 50 mbarn (compared to 190 mb inelastic) (iii) over ~50 cm, if one has a radial displacement of 5 mm, the proton is likely to leave the target, $\phi = 9.52$ mm
- O.K., I wrote and issued a "Change Request " for the above my work plan. → Approved..

On Proton Elastic Scattering, P-Be... In G4 vs data:

Nucl. Phys. 79 (1966) 609-624



Obtained writing a standalone Geant4 application featuring a very simple geometry, a thin Be target (3 cm long) and a detector screen.

Portable to G4 v4p8 and v4p9.

G4 cuts effective X-section

If scattering angle > 3* Mean multiple scatt. & eLoss < ~ 100 MeV, “measured” an effective cross-section of ~ 76 mb.

For a scattering angle greater than 1.5 mRad, only 50.3 millibarns.

PROTON-NUCLEI CROSS SECTIONS AT 20 GeV

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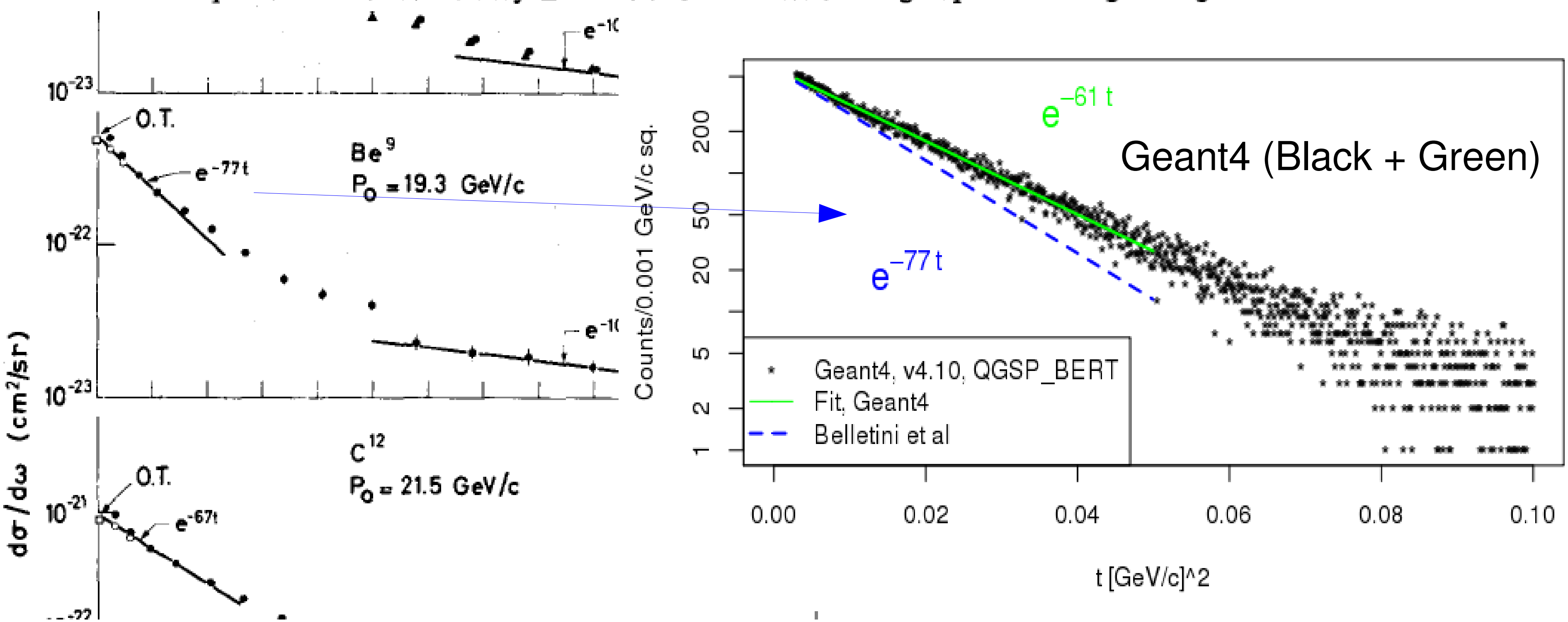
Nucl. Phys. 79 (1966) 609-624

Received 30 September 1965

Abstract: Measurements of the differential cross section of 20 GeV protons scattered elastically and quasi-elastically by a series of nuclei, ranging from Li to U, are presented. The total and the elastic cross sections are also given.

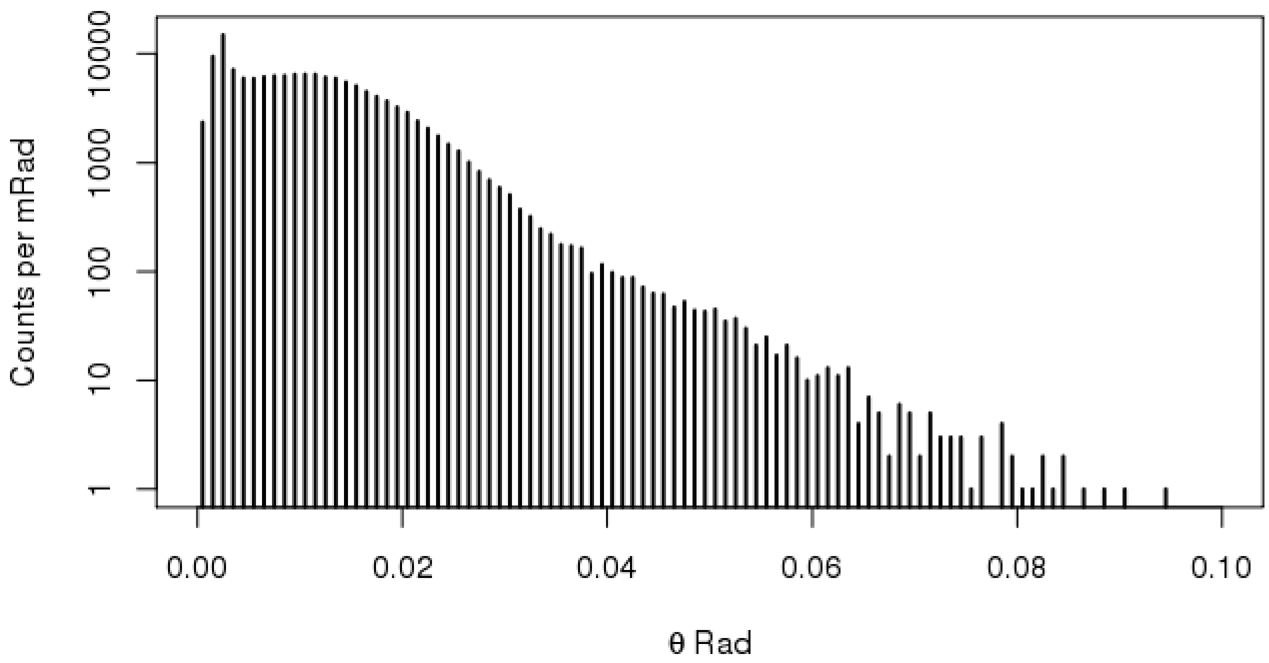
The light nuclei show, at the smallest angles, the characteristic central diffraction peak produced by an absorbing disc; at larger angles the quasi-elastic scattering produced by single nucleons predominates. The heavy nuclei exhibit diffraction rings up to the largest angles



On Proton Elastic Scattering, P-Be... In G4, at 8 GeV

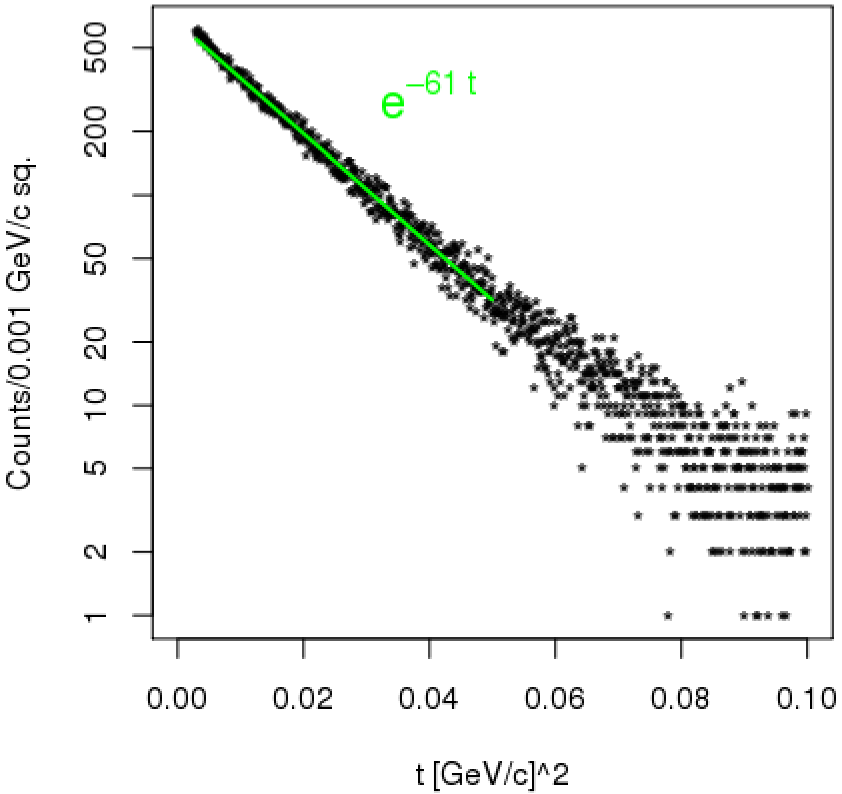
Same t-slope as at 20 GeV (sensible..)

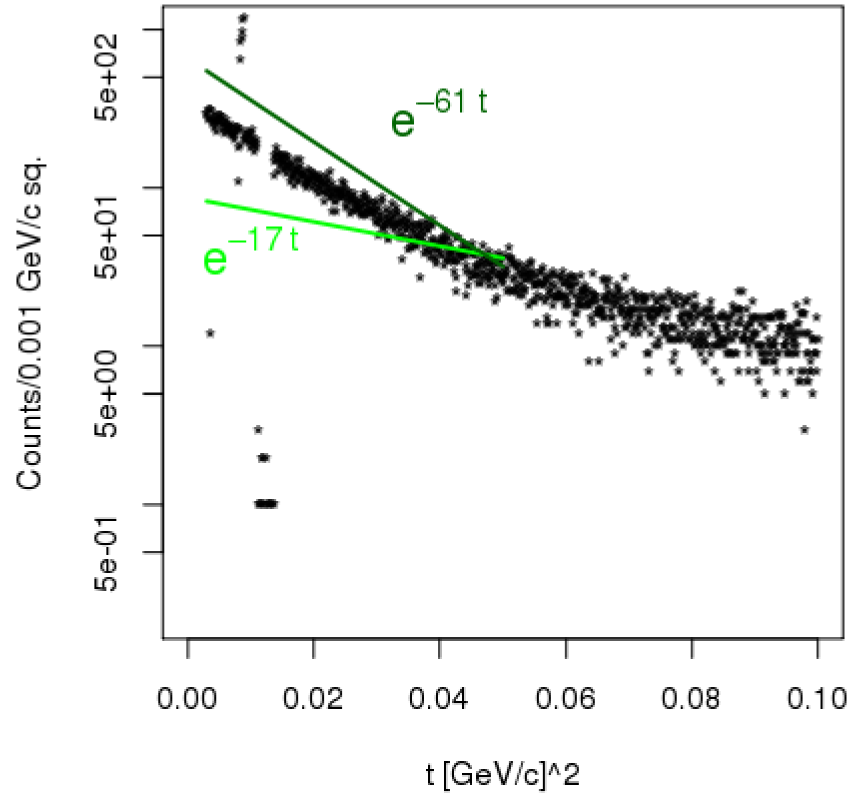
Extract from this an effective angular distribution..



Implemented in BooNEPrimaryGeneratorAction.

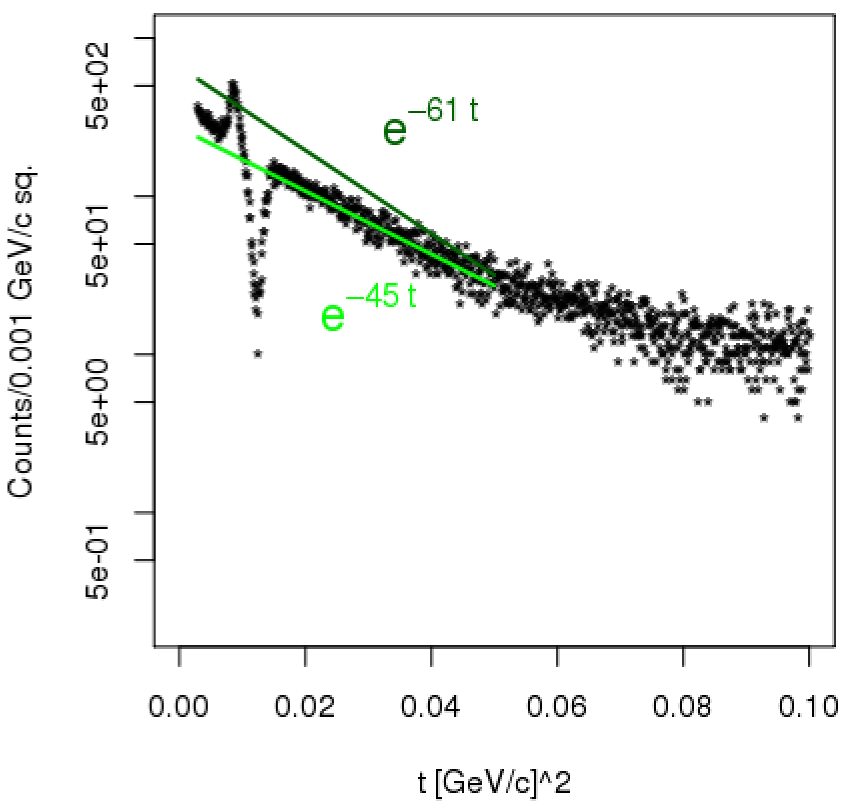
Note: using the same simple G4 standalone Thin target simulation, Using v4p9, one gets:





Plots on the left is obtained with G4 Physics List "QGSP-BERT". On the right hand side, obtained with the "BooNE" Phyisics list, where cross section and models have been "adapted"... The fit is meaningless, but the t-slope has a definite break at t~0.050, hinted from the data, but too high..

Note: using the same simple G4 standalone Thin target simulation, Using v4p8, BooNE Physics list..

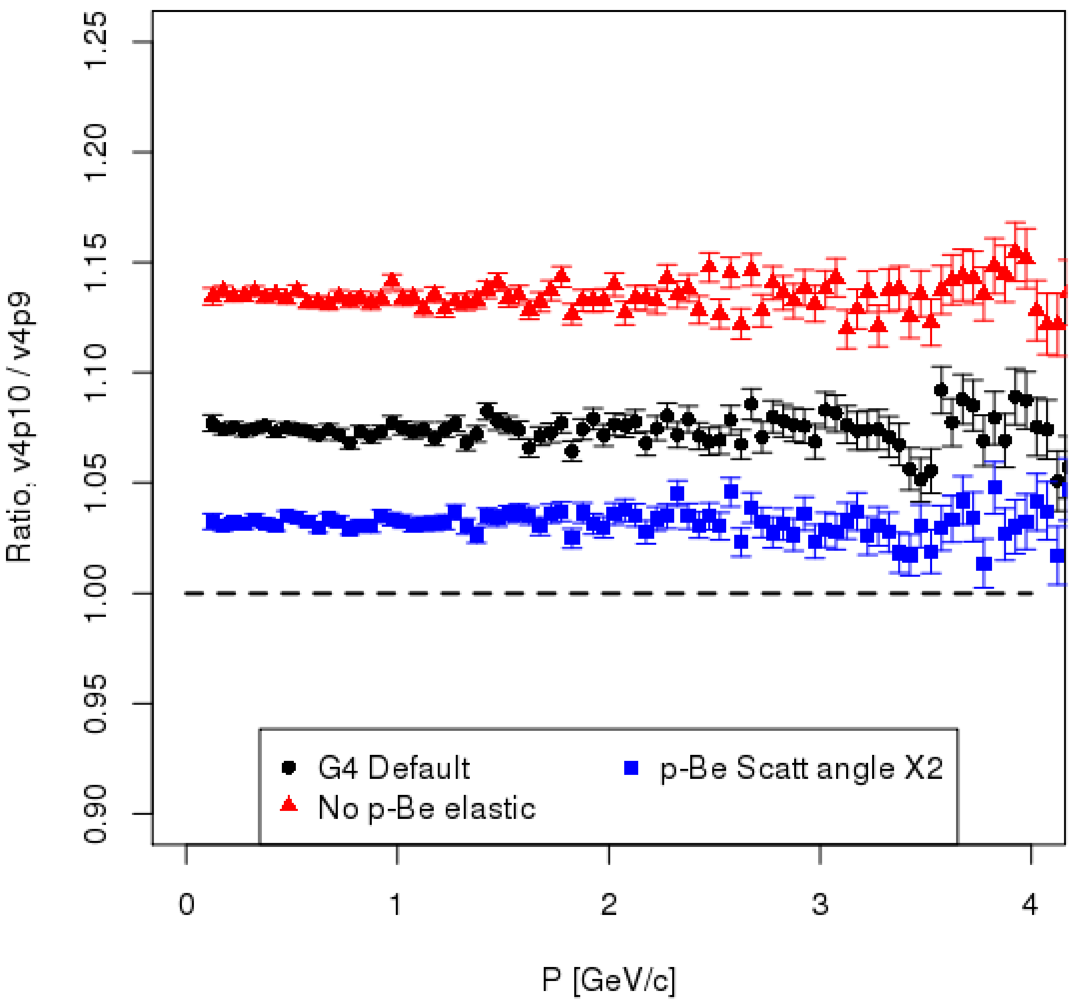


Since the BooNE physics borrows from The native G4 physics lists, changes could have been made.

The glitch at t ~ 0.01 GeV seems to have little impact on the pion production yield in the Be target, as we have successfully compared v4p9 vs v4p8, BooNE Phys. List.

However, the scattering in these two version is clearly too hard, compared to data.

Moving on.. Back to BooNE MC, v4p9 vs v4p10, with HARP/MiniBooNE model as the PrimaryGeneratorAction



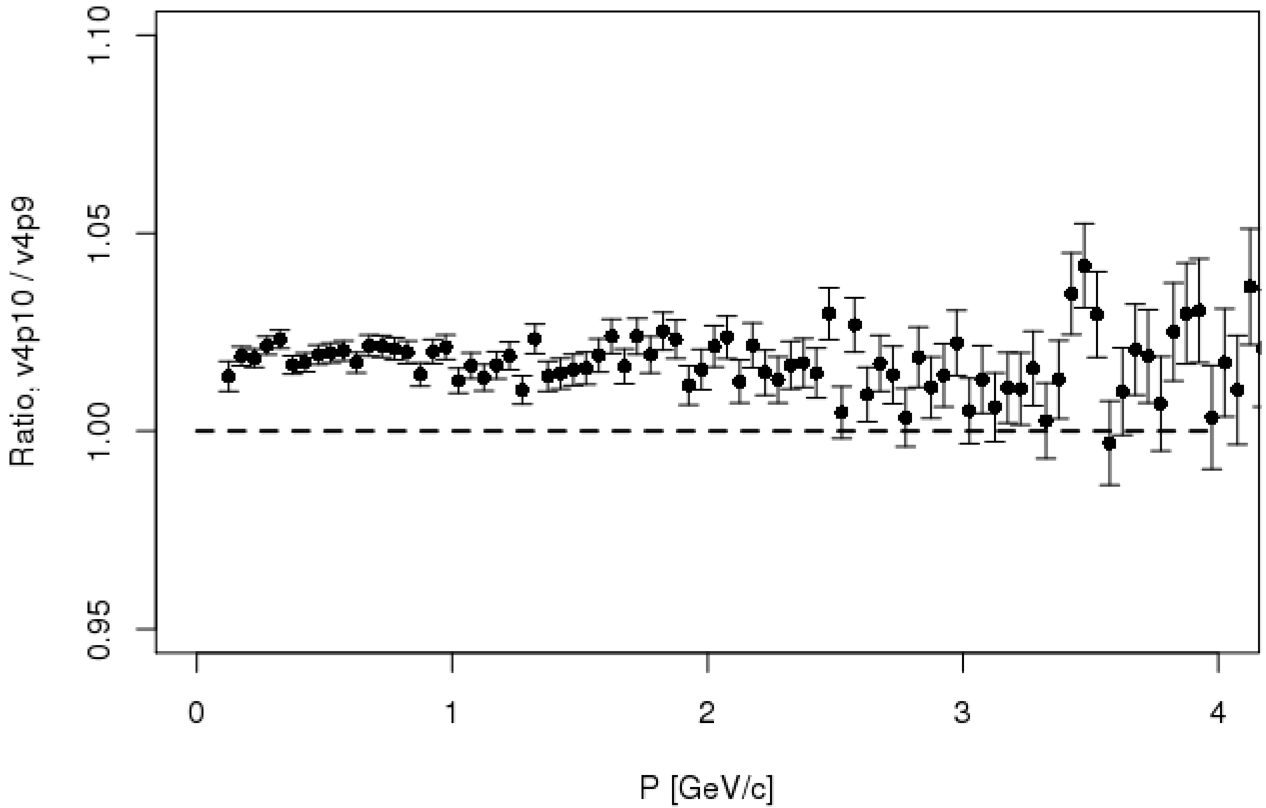
We take the π^+ from the Ntuple taken at the stacking action, candidate tracks whose parent is 0 (i.e., primary tracks.) Their momentum distribution has the same shape, as the distribution being sampled are all derived, "BooNE/HARP", consistently. (Note that we have a cut at 50 MeV in this tuple, hence the first point is not relevant.)

The improved (v4p10, QGSP-BERT) gives a pion yield increase of ~7.3% with respec to v4p9 (or v4p8). Because the scattering is harder in those older versions.

However, if ignore p-Be elastic scattering v4p10one has an excess of pions of about 13.3 % compared to v4p9.

If we (arbitrarily) multiply the scattering angle obtained in the G4 v4p10 QGSP-BERT p-Be scattering model, by two, we have reduction of ~3.3 %

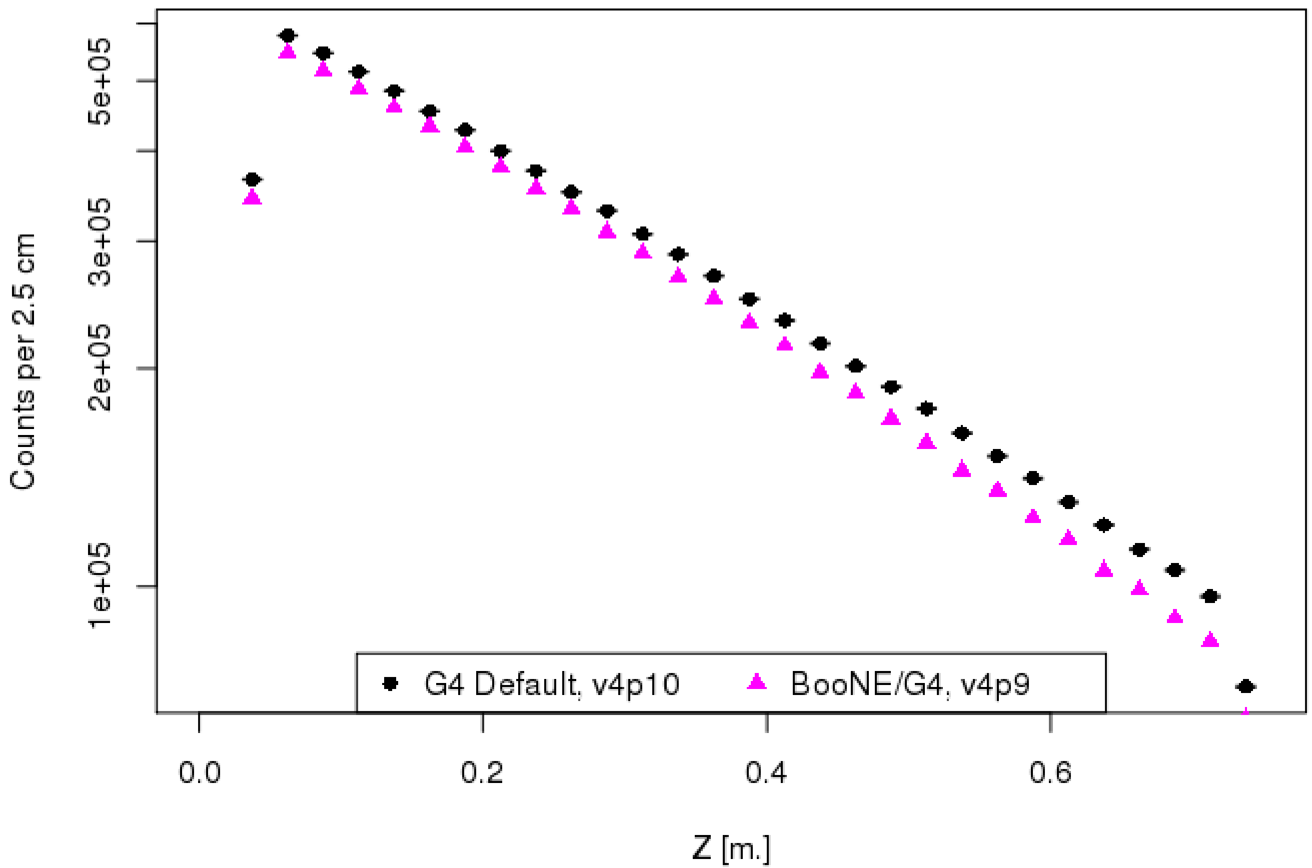
Uncertainty in the p-Be Scattering model: T-slope, 0.77 vs 0.61 inv. GeVsq.



The G4 model of proton-Be elastic scattering model has been replaced in the BooNEPrimaryGeneratorAction class by a simpler model where the elastic cross section is assumed to be 51 mbarn, and the t-slope is 77 inv. GeV/c sq. This reduces a bit the amount of scattering, the scattering model is slightly softer. Note that the scattering angles smaller than 1.5 mRad have been kept (unlike in the Bellitini experiment..)

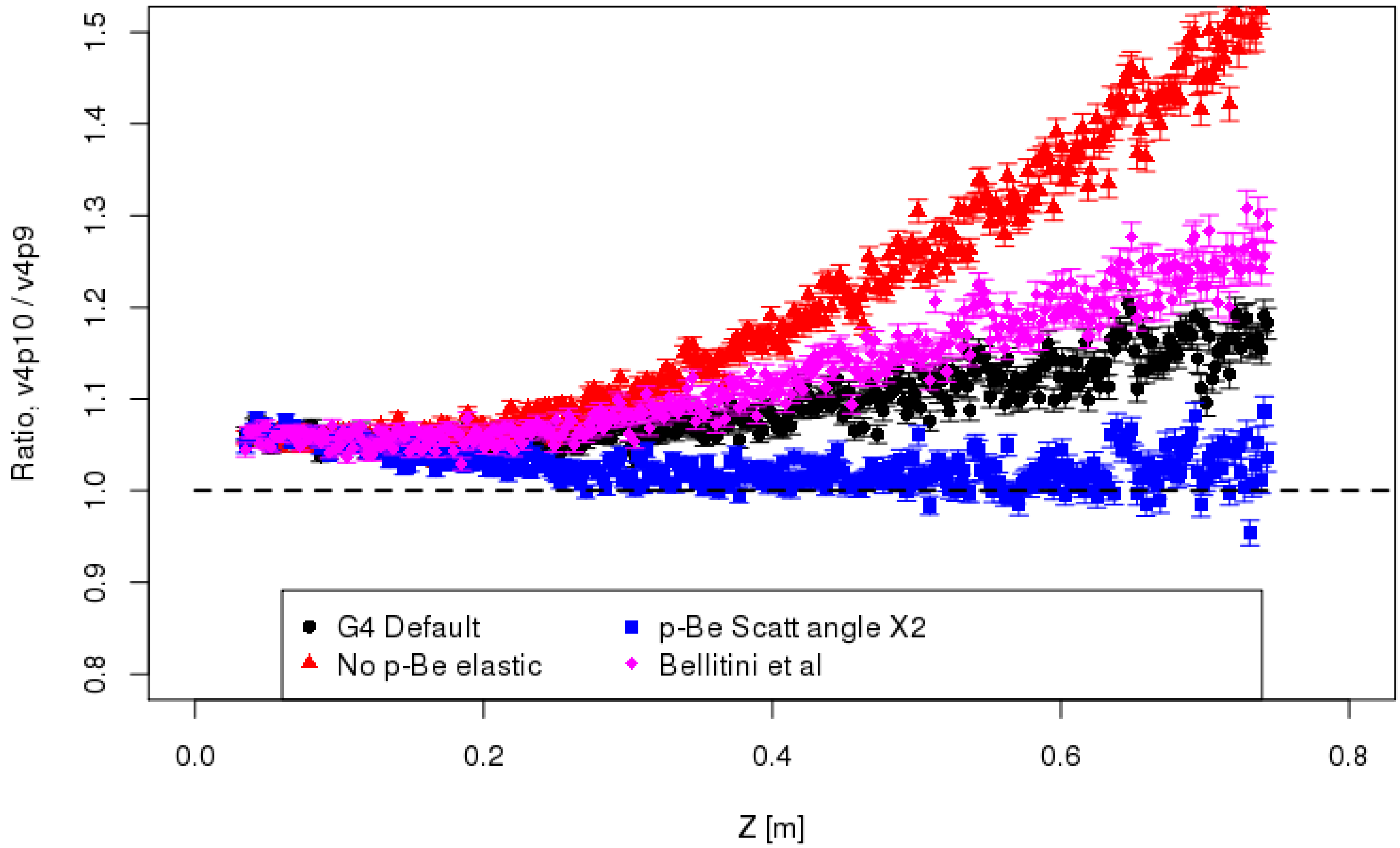
This increases the pion yield at the primary vertex by 1.7 %. Of course, same pion momentum distribution..

Consequently, the Z location of the primary vertex gets slightly modified:



The protons disappear slightly faster in the v4p9 version, as they scatter more. Thus, the focusing of pions of the inelastic interaction. However, there is clearly an other effect: The first few bins are also lower. This is presumably – difficult to prove in any formal way – due to the difference in step length and proper determination of the coordinate of the interaction point.

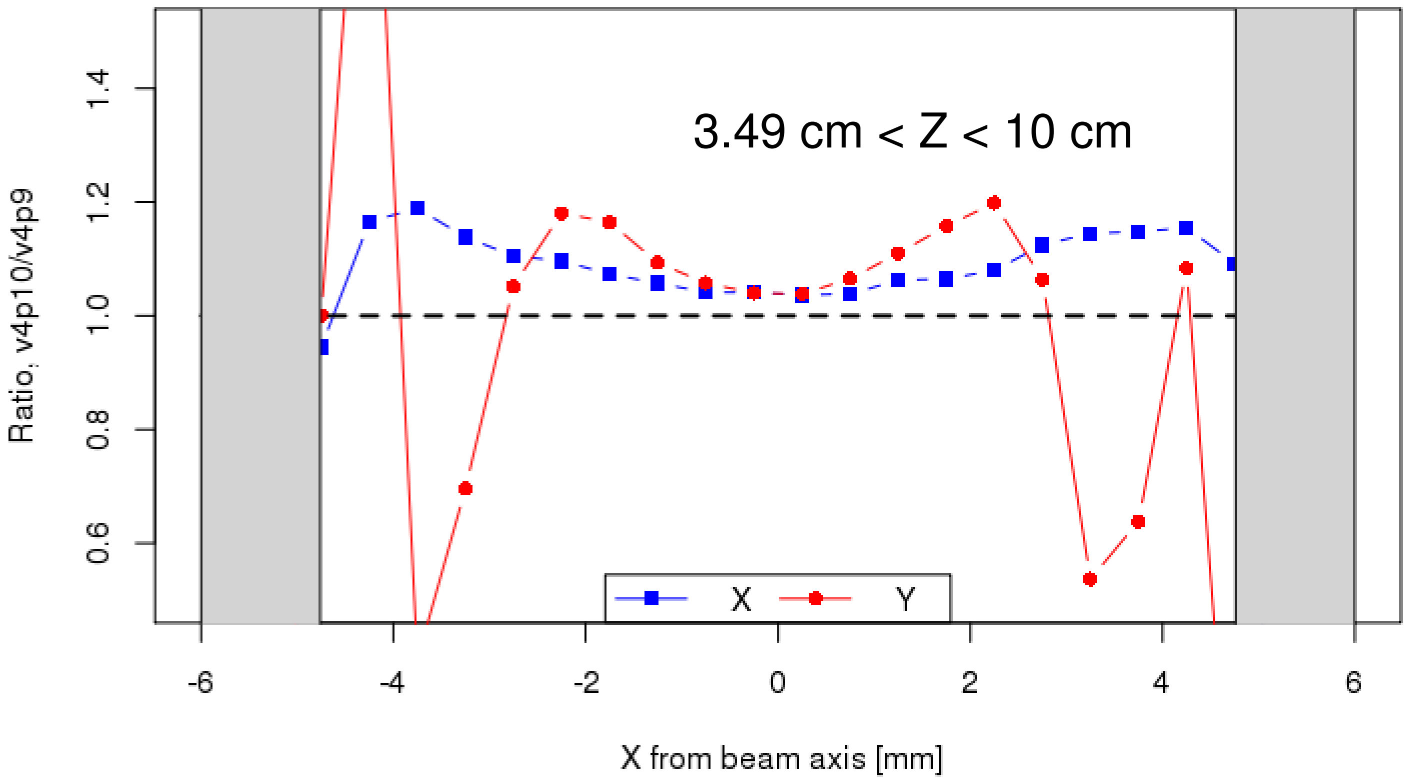
.. More quantitatively...



The ~ 5 % difference at Z = 0 needs some more investigation..

.. … We know the step lengths and exact vertex position are bound to be different...

Fixed step length in v4p10 primary action generator crude tracking vs variable step length in v4p9. We know there is a nonphysical excess of vertices close to the radial edge of the Be slugs.

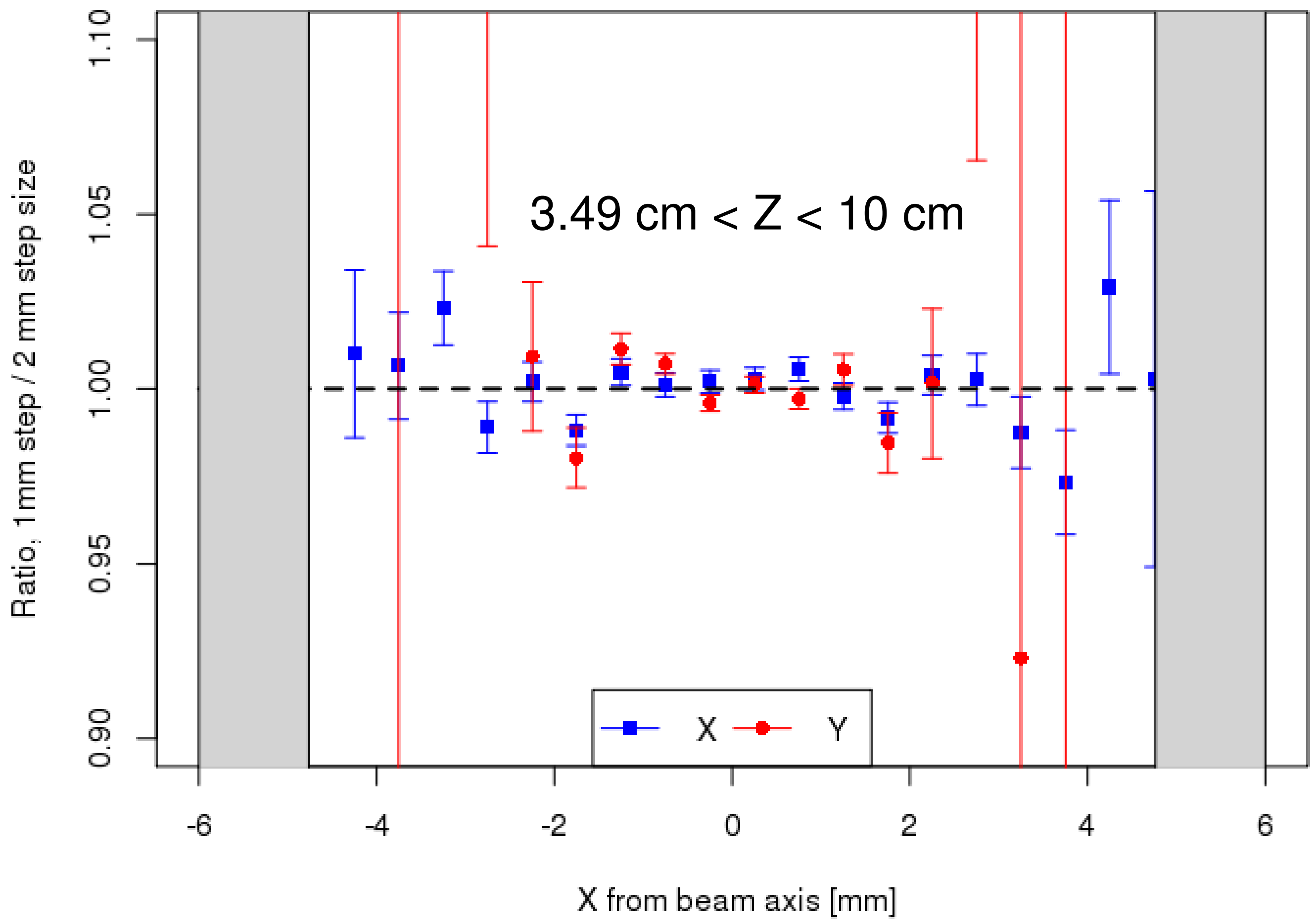


Grey is the radial edge of the target.

We verified that the beam width (1.51 mm, 0.75 mm sigma,) are the same in v4p10 and v4p9
Difference in stepping algorithms the shape, the remaining 3.8 % at X=Y=0. is harder to explain.

If one further restrict the Z-range, down to just 3 cm of Be, difference around 4% remains.
If one uses a very thin proton beam (150 mm X 75 mm), the difference increases to 7% (more scattering..)

Note: Multiple scattering is purely Gaussian in simple v410 HARP/BooNE model (for proton, before inelastic interaction).. Not so in v4p9.



G4 V4p10,

BooNE HARP

Primary model.

The custom proton propagation algorithm in the HARP/BooNE PrimaryGeneratorAction of the v4p10 is stable against a change in the π^+ yield at the Inelastic p-Be collision point, even at short distance... Integrated over all Z, changes < .1%, 1 mm step size to 2 mm step size. A bit worse for 3 mm step size, where a change in the yield of .1 % is seen. 2 mm is reasonable default value for the custom proton separation.

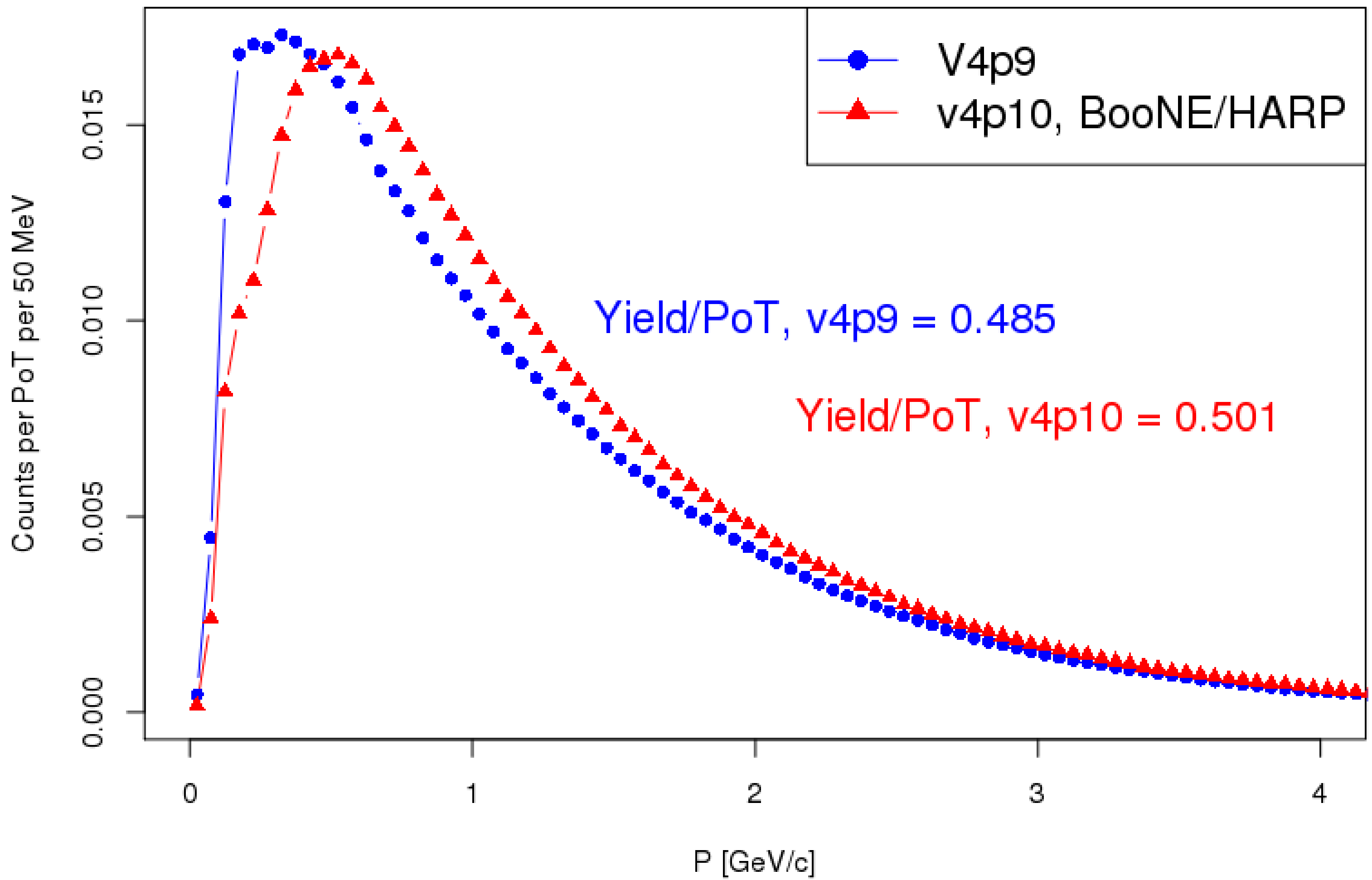
The G4 v4p9 step size is much larger...

If one increases the p-Be Inelastic X-section from 189.3 mb (so-called DEC04 value) to 212.3 mb (the value found in BooNE X-section tables), then the π^+ yield increases by 4.6%.

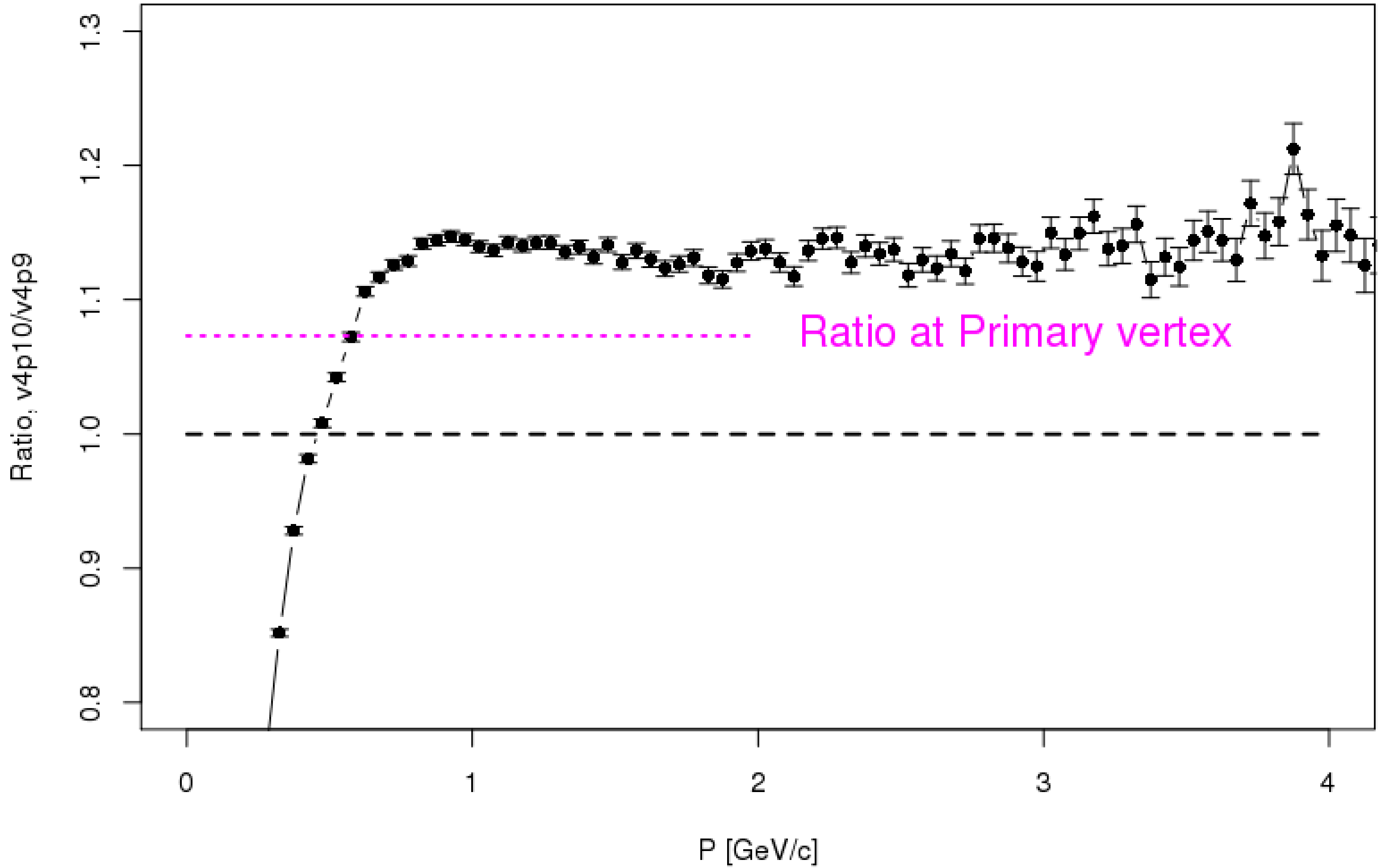
Not 12% (this is a moderately long target)
Additional 4%, on top of the 3.5% discussed on slide 15.

Bottom line: for now, we have to live with a “systematic” tracking uncertainty of ~4%, as the exact root cause (which specific tracing algorithm in v4p9 or v4p8 is the culprit..) is unknown.

Moving On: Inclusive π^+ yield after Horn

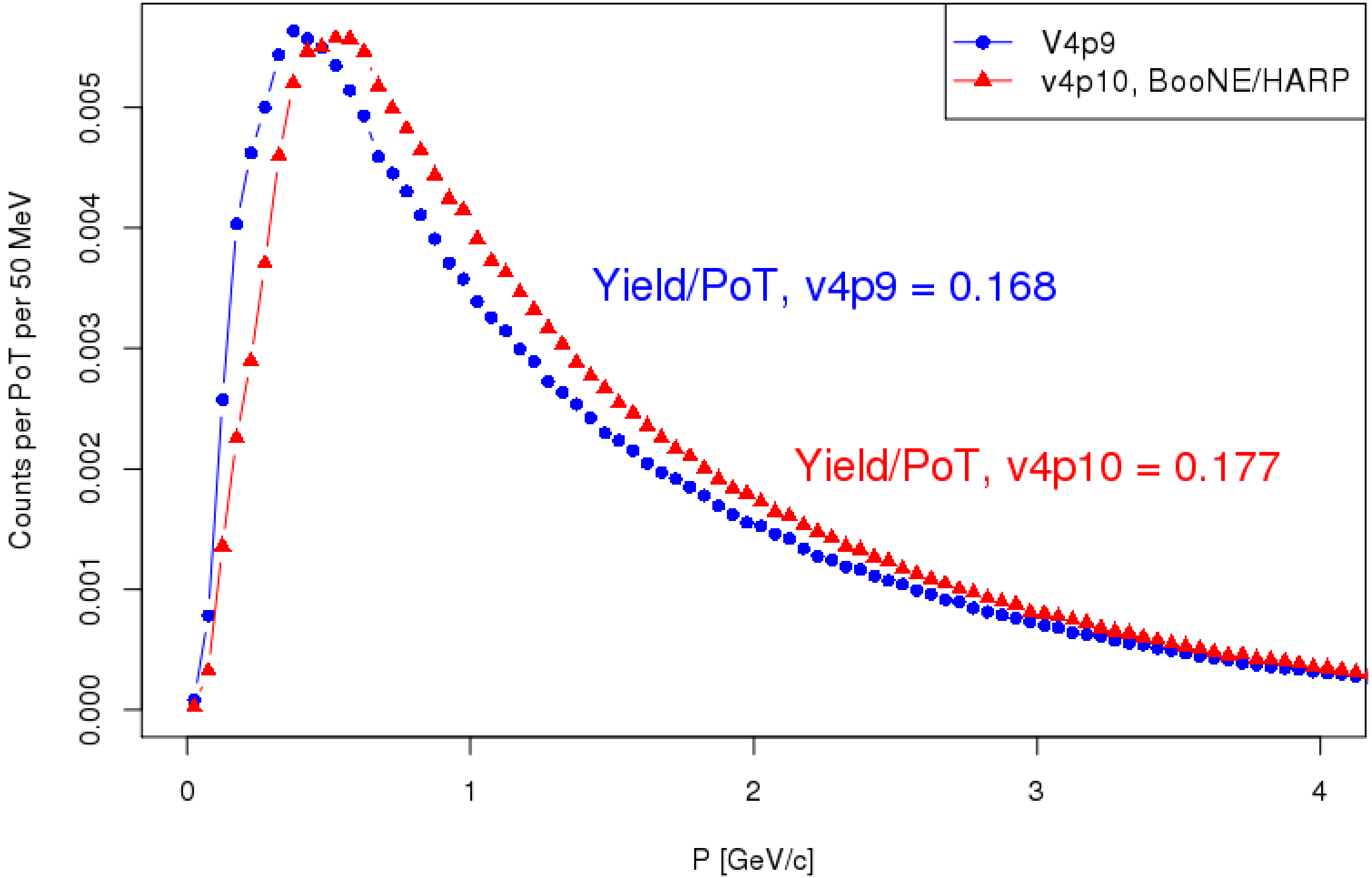


The ratio....



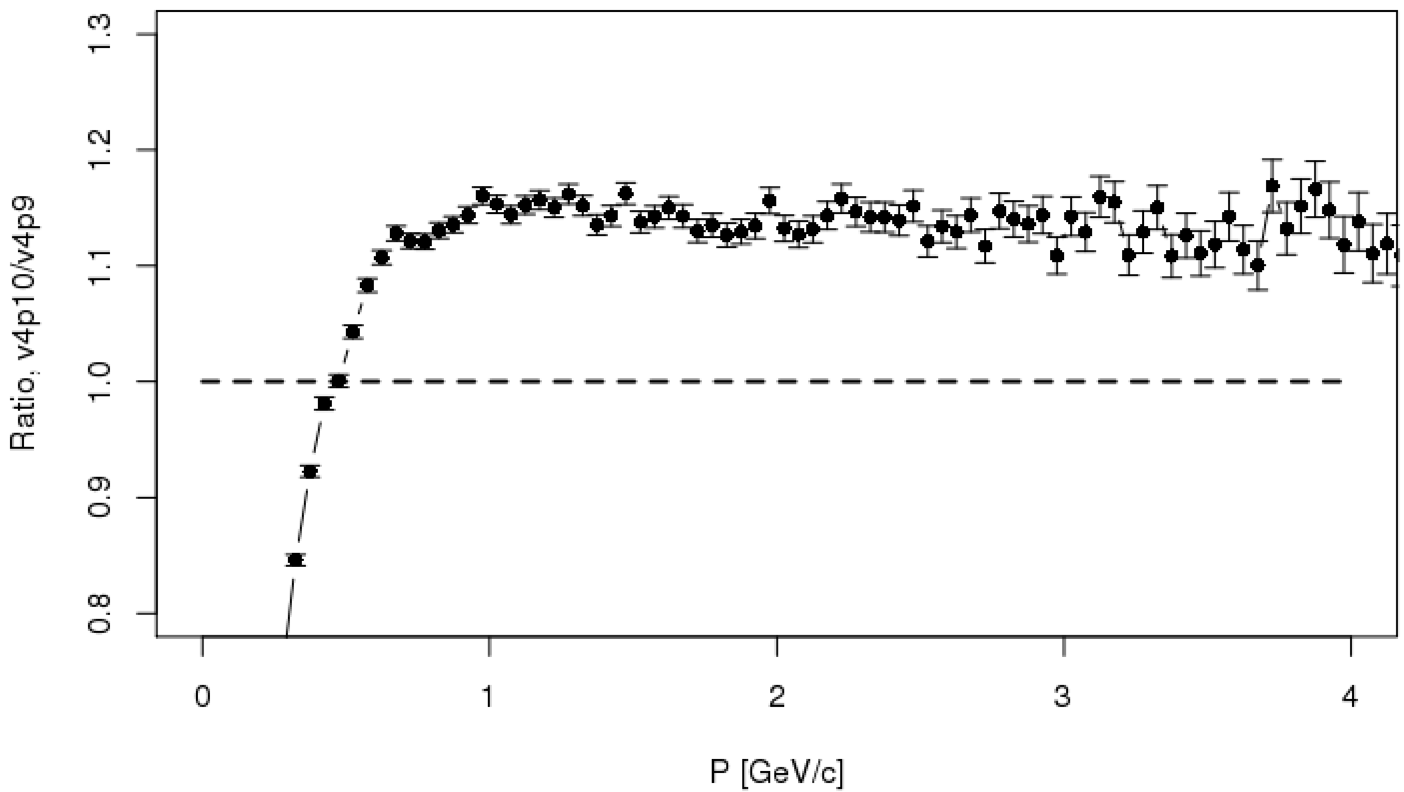
The large difference at low momentum was expected, as the QGSP-INCXXX physics has updated x-section for scattering (inelastic) and absorption processes..
But we also had difference at high momentum.

Inclusive π^+ yield after Collimator



Same behavior as after Horn.. but yield is a factor 3 down...

The ratio....After Collimator.



The large difference at low momentum was expected, as the QGSP-INCXXX physics has updated x-section for scattering (inelastic) and absorption processes..
But we also had difference at high momentum.

All diagnostics that were in v4p9 were preserved in v4p10, including the various geometry files.

Alpha version of BooNE running with G4 v4.10.1.p03 with BooNE/HARP Production model available.

However, Neutrino fluxes not checked.. Need more work...as off Friday, April 8 …

Addendum/errata : April 12.

Legends on slide 19 & 21.
Neutrino spectrum fixed (small bug in the Dk2nu Ancestor list).

Neutrino flux, from $\pi^+ \rightarrow \mu^+ \nu_\mu$